



بسم الله الرحمن الرحيم

**Sudan University of Science and Technology**  
**College of Graduate Studies**

**Master Program**  
**Fuzzy Logic Control (FLC)**

**Lecture (1)**

**Instructor: Dr. Mohammed Elnour A/Alla**

بسم الله الرحمن الرحيم

# **Sudan University of Science and Technology**

## **School of Electronics Engineering**

### **Fuzzy Control**

### **التحكم الغامض**

### **Lecture (1)**

**Instructor: Dr. Mohammed Elnour A/Alla**

# Course Outlines

- Introduction
- Fuzzy Set Theory
- Fuzzy Relations
- Fuzzy Rules and Fuzzy Reasoning
- Fuzzy Inference systems
- Introduction to MATLAB Fuzzy logic tool box
- Fuzzy decision making

# References

1. Leonid Reznik " Fuzzy controllers", ebook
2. Jan Jantzen , "Foundations of Fuzzy Control", 2007  
John Wiley & Sons Ltd, ebook
3. Kevin M. Passino, "Fuzzy Control ", ebook
4. S. N. Sivanandam, et, al 'Introduction to  
Fuzzy Logic using MATLAB" ebook  
(numerical Exs)
5. Fuzzy Logic Toolbox. For use with Matlab.  
Users guide. Ver. 2

# .....References

6. J. S. R. Jang “Neuro Fuzzy and Soft Computing. A comprehensive approach to Learning and Machine Intelligence
7. Fuzzy sets and system; Theory and applications  
ebook
8. Guanrong Chen (Introduction to Fuzzy Sets, Fuzzy Logic and Fuzzy Control Systems) ebook
9. S. Sumathi and Surekha P. (Computational Intelligence Paradigms :Theory and Application using matlab)

# INTRODUCTION

- *I understand that you want to start a design immediately.*
- *As you know nothing about fuzzy control, we will base our design just on our human experience.*
- *Let us consider a classical control problem. We want to control the boat movement which we should drive along the straight line from point A to point B.*
- ***How will you design a controller to do it?***

# Introduction ...

- *Well, firstly I must derive a mathematical model of the plant and then develop a mathematical model of a controller.*
- **And how will you develop the controller model?**
- *I will apply one of the design methods, e.g., pole placement design, and obtain a transfer function for the controller.*



# Introduction ...

- *OK. Now suppose we do not know exactly the mathematical model of our plant. Moreover, we do not know any classical design method. What can we do then?*
- *In other words, is it possible to do control without the mathematical model?*
- *Actually in our daily life we do many control activities without solving differential equations. e.g: ride bicycles, park cars etc..*

# Introduction ...

- ❖ *Try to use your own experience. How did you drive a boat in your childhood?*
- ❖ *I turned the rudder left or right depending on the position of a boat.*
- ❖ *Great! So we can say that:*
  - *if the boat is situated exactly on the line we should not do anything,*
  - *if the boat is situated to the left of the line we should turn the rudder to the right (let us call this direction positive),*
  - *and if the boat is positioned to the right of the line we should turn the rudder to the left.*

# Introduction ...

- Now let us try to formulate this control law as a set of rules.
- **If deviation is *zero* then turn is *zero*.**
- **If deviation is *positive* then turn is *negative*.**
- **If deviation is *negative* then turn is *positive*.**

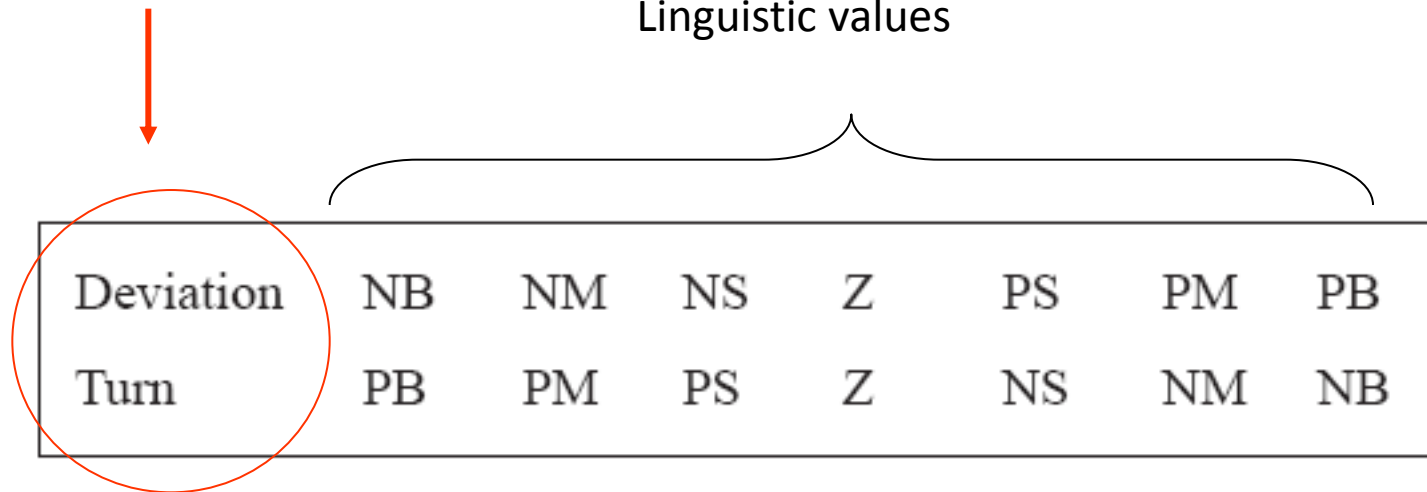
**Rule base**

# Introduction ...

- *Are you sure this table can control the boat movement?*
- *Of course, very roughly.*
- *To improve the control quality and make our controller more reactive, we need to increase the number of values describing each variable.*
- *Now let us use **small**, **medium** and **big** values for both the **deviation** and the **turn**. Then we obtain the rules table:*

Linguistic variables

Linguistic values



Deviation	NB	NM	NS	Z	PS	PM	PB
Turn	PB	PM	PS	Z	NS	NM	NB

**NB: Negative Big, NM: Negative Medium, NS: Negative Small**  
**Z: Zero, PS: Positive Small, PM: Positive Medium**

## What is Fuzzy Control?

Fuzzy control is one of the *intelligent control* techniques that uses *fuzzy logic* to model the control strategies of an expert operator, which are described in linguistic fuzzy (imprecise) terms .

# What Is Fuzzy Logic?

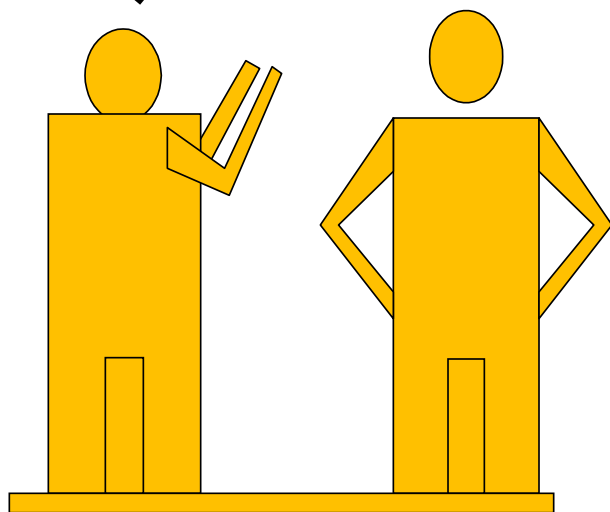
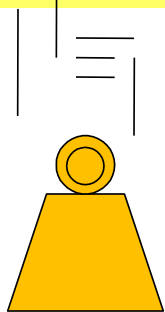
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- ❑ *Humans are more efficient in dealing with fuzzy data than computers (e.g crossing a busy road).*
- ❑ *Fuzzy logic is used to convey the human capability of handling fuzzy information to the computer*
- ❑ *It is a mathematical tool to capture and handle the fuzzy data that is used in the natural language*

# What Is Fuzzy Logic?

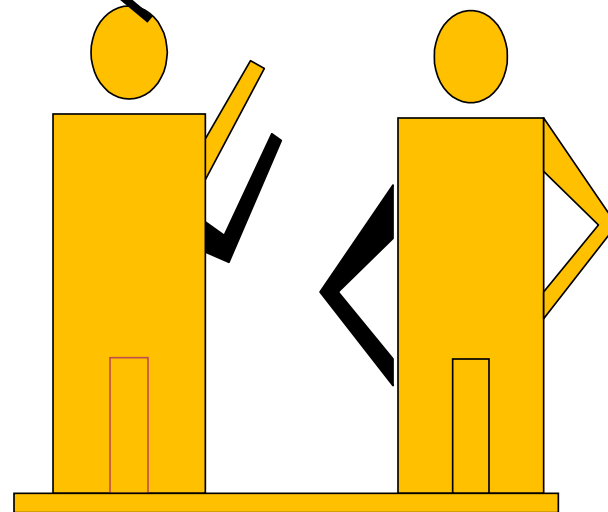
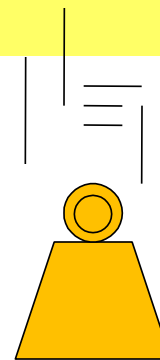
## *Significance of Precision in the Real World*

A 400 kg mass is  
approaching your  
head at 50 m/sec



Precise man

Look out !!



Fuzzy man



# How are you going to park a car?



You have to switch to reverse, then push an accelerator for 3 minutes and 46 seconds and keep a speed of 25km/hr and move to 5m back after that try ...

**Crisp man**



It's eeeeasy!  
Just move slowly back and avoid any obstacles

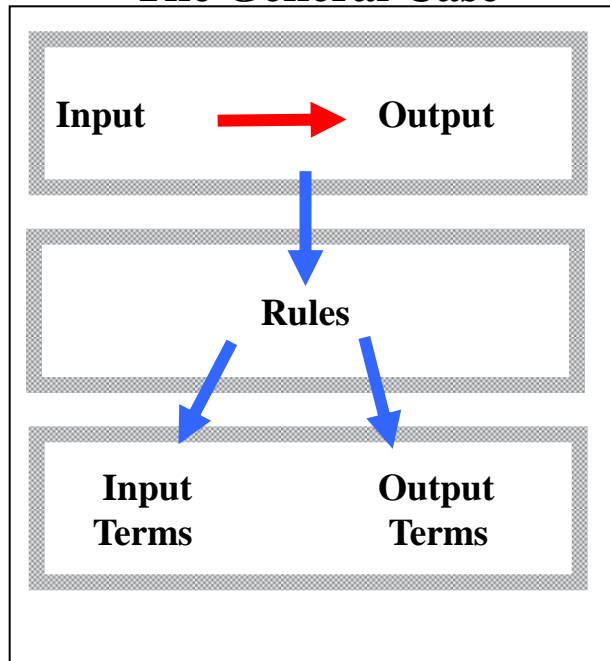
**Fuzzy man**

# What Is Fuzzy Logic?

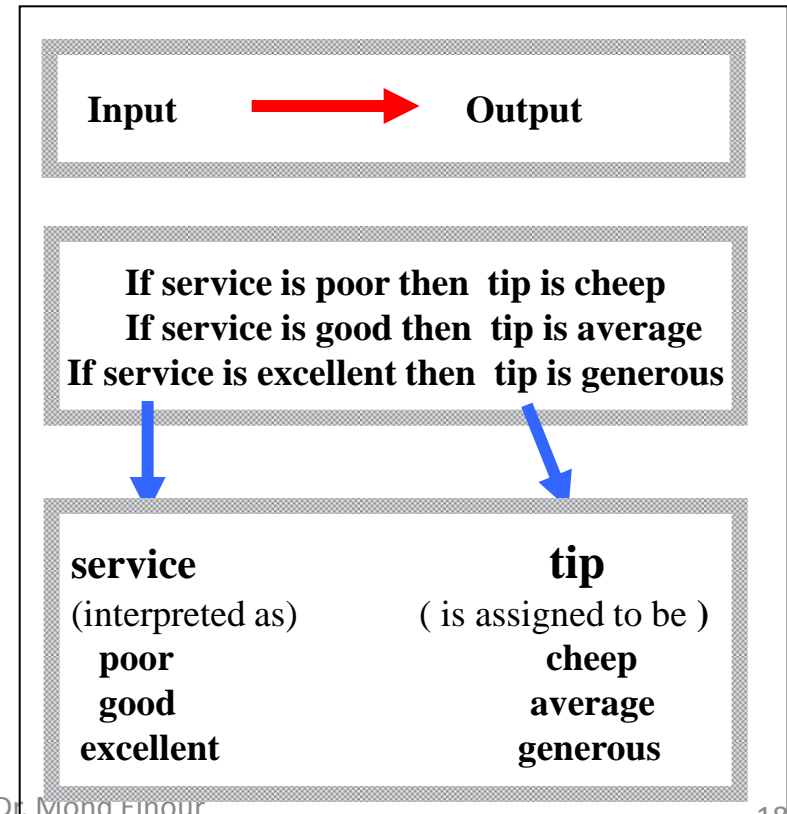
## -The Big Picture-

FL maps an input space to an output space using a list of if-then rules

### The General Case

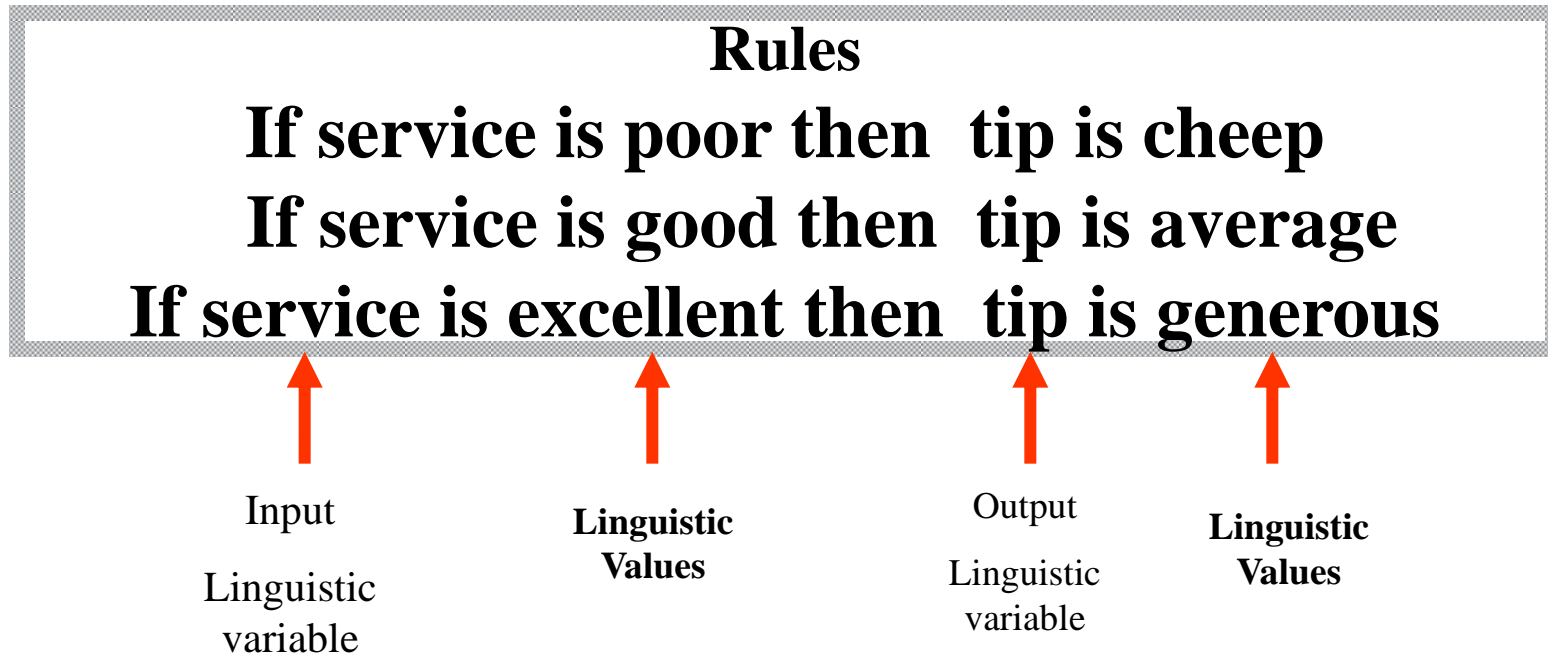


### A Specific Example



# What Is Fuzzy Logic?

-Linguistic Rules, Variables and values



***Linguistic Rules*** of a fuzzy systems are the laws it execute

***Linguistic variables*** defines a concept of our everyday language

***Linguistic values*** describe the characteristic of the *Linguistic variables*

Fuzzy Logic Control, By: Dr. Mohd Elnoor

A/Alla

# Why fuzzy logic?

*Fuzzy Logic can:*

- ☐ *Represent vague language naturally*
- ☐ *Enrich not replace crisp sets*
- ☐ *Allow flexible engineering design*
- ☐ *Improve model performance*
- ☐ *Are simple to implement*
- ☐ *And best of all, they often work!*

# Why do we need this new theory?

## Limitations of conventional controllers

- Plant nonlinearity. The efficient linear models of the process are too restrictive. Nonlinear models are computationally intensive and have complex stability problems.
- Plant uncertainty. A plant does not have accurate models due to uncertainty and lack of perfect knowledge.
- Uncertainty in measurements. Uncertain measurements do not necessarily have stochastic noise models.
- Temporal behaviour. Plants, controllers, environments and their constraints vary with time. Moreover, time delays are difficult to model.

# Why do we need this new theory?

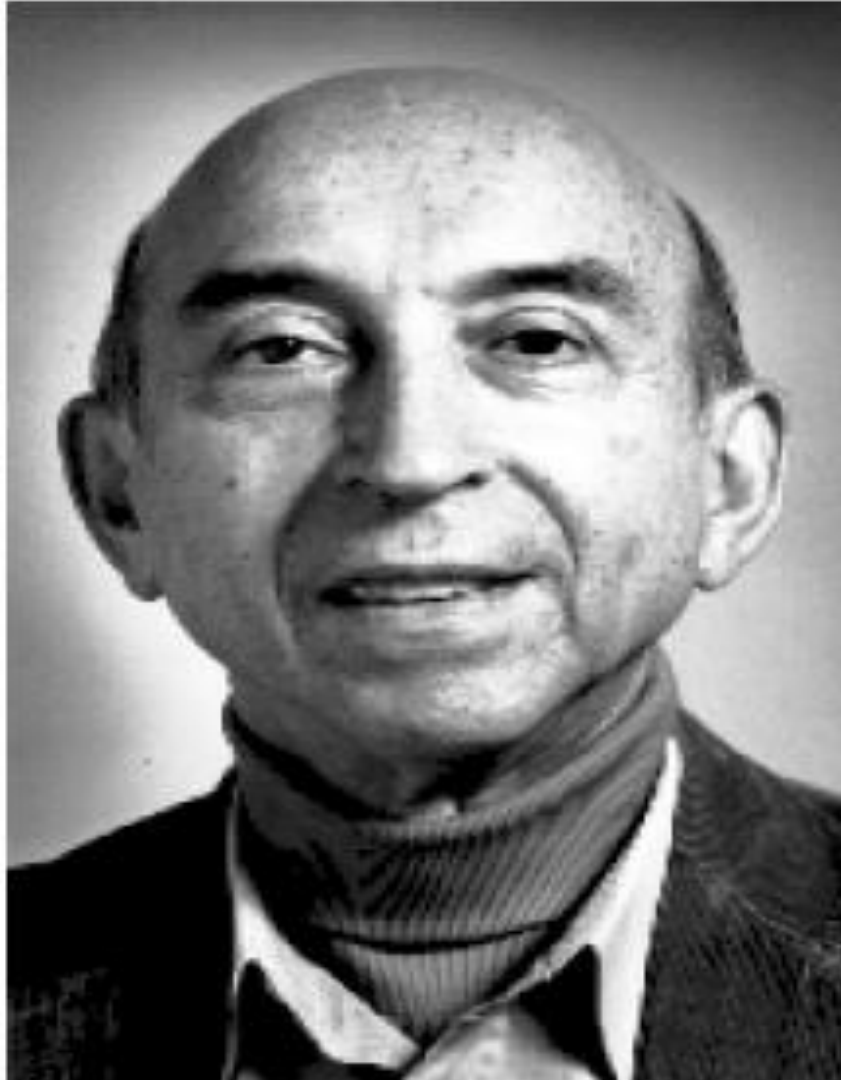
## *Benefits of the fuzzy controllers*

- *Fuzzy controllers are more robust than PID controllers because they can cover a much wider range of operating conditions than PID can, and can operate with noise and disturbances of different natures.*
- *Developing a fuzzy controller is cheaper than developing a model-based or other controller to do the same thing.*
- *Fuzzy controllers are customisable, since it is easier to understand and modify their rules, which not only use a human operator's strategy but also are expressed in natural linguistic terms.*
- *It is easy to learn how fuzzy controllers operate and how to design and apply them to an application*

# The root and development of fuzzy logic

- *Fuzzy set theory was introduced by Professor Lotfi Zadeh (USA) in 1965. as an extension of the classical set theory*
- *1972 First working group on fuzzy systems in Japan by Toshiro Terano*
- *1973 Paper about fuzzy algorithms by Zadeh (USA)*
- *1974 Steam engine control by Ebrahim Mamdani (UK)*
- *Too many events, inventions and projects to mention till 1991*
- *After 1991 fuzzy technology came out of scientific laboratories and became an industrial tool.*
- *In the last two decades, the fuzzy sets theory has established itself as a new methodology for dealing with any sort of ambiguity and uncertainty.*

# Zadeh (USA)





# What are the main areas of fuzzy logic applications?

The following list includes just a small number of successful projects and is intended to demonstrate a huge diversity of possible applications.

- ❖ Automatic control of dam gates for hydroelectric power plants (Tokyo Electric Power.)
- ❖ Simplified control of robots (Hirota, Fuji Electric, Toshiba, Omron)
- ❖ Camera-aiming for the telecast of sporting events (Omron)
- ❖ Efficient and stable control of car engines (Nissan)
- ❖ Cruise-control for automobiles (Nissan, Subaru)
- ❖ Automatic transmission of automobiles (see next slide)
- ❖ Substitution of an expert for the assessment of stock exchange activities (Yamaichi, Hitachi)
- ❖ Optimised planning of bus timetables (Toshiba, Nippon-System, Keihan-Express)
- ❖ Archiving system for documents (Mitsubishi Elec.)
- ❖ Prediction system for early recognition of earthquakes (Seismology Bureau of Metrology, Japan)



*1996 Saturn SL1 and Mitsubishi Galant ES and LS are equipped with fuzzy controlled automatic transmission*



## Applications cont.

- ❖ Medicine technology: cancer diagnosis (Kawasaki Medical School)
- ❖ Automatic motor-control for vacuum cleaners with a recognition of a surface condition and a degree of soiling (Matsushita)

During the 'fuzzy' revolution, the fuzzy technology was introduced not only to a world of complex industrial projects, but to simple everyday home appliances: next are some examples

## Panasonic®/National® Fuzzy Logic



### Rice cooker

Fuzzy logic controls the cooking process, self adjusting for rice and water conditions

# National® Deluxe Electric Fuzzy Logic



## Thermo pot

This unit represents the best technology available in producing clean boiled water on demand for making tea. It is fuzzy logic computer controlled